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# THE INTERSECTION OF SCRATCH AND PROBLEM SOLVING: INSIGHTS FROM A BIBLIOMETRIC ANALYSIS

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## ABSTRACT

***This study presents a bibliometric analysis of the relationship between scratch, a popular visual programming language, and the development of problem-solving skills. Using data from related scholarly publications over the past decade, this study aims to identify research trends, collaboration patterns, and the impact of scratch on learners' problem-solving abilities. The analysis shows a significant increase in publications exploring the use of scratch to enhance problem-solving skills. Key emerging topics include the development of computational thinking, the implementation of project-based learning strategies, and the integration of scratch into formal and informal education curricula. The research also revealed a strong international network of collaboration among researchers in this field. The findings provide valuable insights for educators, policymakers, and researchers regarding the potential of scratch as a tool for developing problem-solving skills. The study also identified gaps in the literature and suggested directions for future research to better understand the effectiveness of scratch in enhancing problem-solving abilities across different age groups and educational settings.***

**KEYWORDS:** Scratch, Problem Solving, Bibliometric.

## 1. INTRODUCTION

Problem-solving ability is considered important because it can reflect students' readiness to face the challenges they encounter in everyday life (Dunbar, 2007). The development of problem-solving skills will indirectly prepare students to think independently and

critically and to be innovative (Rozandy & Koten, 2021). Students generally struggle to change strategies in the middle of the problem-solving process (intra-task flexibility) (Arianto, 2024). This requires more time and practice to develop. The components that should be the main focus in problem-solving are critical reasoning, creativity, decision-making, adaptation, and collaboration. To develop students' problem-solving skills, these five components must be well mastered by students (OECD, 2017).

The development of problem-solving skills is a goal of the Indonesian education curriculum, whether the 2013 curriculum or the current independent curriculum. While numerous studies have explored the use of scratch to enhance problem-solving skills, significant gaps in the literature remain to be further investigated. First, most research has focused on elementary and middle school students, leaving a gap in understanding how scratch influences problem-solving abilities in higher education and among adult learners. Second, while international collaborations have been explored, there is limited insight into how different educational contexts and cultural differences affect the outcomes of Scratch-based learning. Third, existing studies have not fully examined the long-term impact of scratch on problem-solving skills, particularly regarding how these skills translate into real-world applications. Finally, while scratch is widely used as a tool for teaching computational thinking, its specific effectiveness in fostering creativity, critical thinking, and decision-making in problem-solving remains underexplored. In light of these gaps, the following research questions are posed to guide this study: 1) What are the key trends in research related to scratch and problem-solving skills over the past two decades? 2) How have international collaborations influenced the development of Scratch-based teaching methods for problem solving? 3)What are the gaps in the literature regarding the impact of scratch on problem-solving abilities across various educational contexts? 4)How can scratch be optimized to enhance problem-solving skills, and what areas need further exploration in future research.

Indonesian education currently focuses on developing 21st-century skills, namely problem-solving skills (Eisner, 2021). This aims to improve the quality of human resources capable of competing in the era of globalization. Based on the PISA framework, the competencies required for problem-solving include the ability to identify problems. This relates to students' ability to understand the problem at hand, including concepts and information that can be used for problem-solving. Furthermore, students must be able to formulate problem-solving strategies and develop the right plan to solve the problem. The selection of the right solution will affect the ability to implement it and to reflect on and evaluate what has been done during the problem-solving process (Herro et al., 2022).

The main objective of mathematics learning is to develop logical and critical thinking skills that support students in problem-solving (Lastuti, 2018). The development of logical thinking skills can improve a person's ability to identify a problem or condition being experienced and determine a solution (Arifin et al., 2020). Through mathematical learning, students are expected to recognize and apply mathematical concepts in everyday life (Muna et al., 2023). The ability to abstraction, generalization can be developed through mathematics learning. Mathematics learning needs include a relevant, structured curriculum, competent, qualified teachers, and adequate learning facilities and resources. Innovative and varied learning methods, effective evaluation and feedback, and a supportive learning environment are also very important for achieving learning goals (Putri et al., 2023). By meeting these needs, mathematics learning can run more optimally and produce students who can apply mathematical concepts in various aspects of life.

According to the National Council of Teachers of Mathematics (NCTM), the purpose of mathematics learning is to develop communication, representation, reasoning, critical thinking, and problem-solving skills (Bossé et al., 2010). These abilities must be developed through mathematics learning (Khikmiyah & Midjan, 2017). Recent studies in mathematics didactics emphasize that effective development of problem-solving competence depends not only on student practice but also on specific teacher knowledge, task design, and the management of errors and affective blocks during problem-solving. Empirical investigations in PNA have detailed frameworks of teacher knowledge necessary for teaching problem solving (Piñeiro et al., 2019), analyzed common sources of student errors in algebraic problem solving (Pérez et al., 2019), and documented how instructional routines can lead to a predominantly "school-style" approach that overlooks exploratory strategies—highlighting the need for pedagogical innovations that foster strategic flexibility and creativity. Program for International Student Assessment (PISA). An institution that conducts surveys of education systems around the world, measuring the abilities of 15-year-old students; one focus is students' problem-solving skills (OECD, 2019). Problem-solving skills help students face and solve everyday problems beyond the school curriculum. NCTM focuses on improving the quality of mathematics education. Of the five focuses on developing mathematical skills put forward by NCTM, one is problem-solving (Allen et al., 2020).

In early-grade settings, research shows that students gradually shift from informal strategies to visual representations when engaged in rich problem-solving tasks, underscoring the importance of well-designed instructional strategies. Furthermore, at the basic education level, didactic strategies aimed at promoting problem-solving skills have been shown to support the development of mathematical thinking, presenting both

challenges and opportunities for teacher practice (Pérez et al., 2019). These findings reinforce the argument that the design of tasks and teaching strategies is a critical factor in mathematics learning — not only for problem-solving performance but for the development of deeper mathematical thinking.

Mathematics learning in Indonesia currently focuses on developing essential abilities in students, enabling them to play an active and effective role in everyday life. The current Indonesian mathematics learning objectives develop critical and logical thinking, problem-solving, abstraction and generalization, quantitative abilities, communication, and the application of mathematical concepts in everyday life (Marisa, 2021). Based on this, it can be concluded that one of the abilities Indonesian students must master is problem-solving, enabling them to think effectively in everyday life. This problem-solving ability is important because it supports the development of other mathematical abilities, such as critical and logical thinking, analysis and synthesis, abstraction, generalization, quantitative reasoning, representation, communication, and creativity (OECD, 2012). Therefore, it can be concluded that problem-solving ability is a crucial skill students must master.

Problem-solving underscores a shift towards promoting higher-order thinking skills and problem-solving abilities among students, moving beyond traditional rote learning methods (Sugiarni, 2024). Problem-solving skills can be developed through STEM-based learning (Science, Technology, Engineering, and Mathematics). STEM learning combines science, technology, engineering, and mathematics, aiming to encourage students to think thoroughly so they can integrate several fields of science in problem-solving activities (Kırıcı & Bakırcı, 2021; Ng et al., 2023). STEM encourages students to think creatively in solving problems, collaborating, and developing prototypes. Increased Effectiveness Learning through digital media can improve student understanding through interactive visualization, enable experiential learning through virtual simulations, facilitate more personalized and adaptive learning, provide flexibility of time and place of learning, improve digital literacy, prepare students for the digital age and develop relevant technology skills (Vargas-Hernández et al., 2024).

One STEM-based learning approach that can improve problem-solving skills is learning with the Scratch application. It is a code-based application that beginners can use easily. Currently, the use of scratch applications in the development of learning media is increasingly widespread. Scratch is one application that can be said to provide benefits in the learning of mathematics, as its use requires computational thinking (Wang et al., 2022). When using scratch, users do not need proficient programming skills because it uses a drag-and-drop interface. The scratch application supports a variety of languages so that everyone can use it. Hartono, 2024, before beginning a game, the teacher has the opportunity to assess the game and its environment. This encourages students to take on additional tasks assigned by their teachers, such as working with peers or in groups. During the action, the teacher reminds herself not to intervene and encourages students to continue playing according to the rules.

In summary, at this stage, players aim to win (e.g., a prize) and earn as many points as possible. Currently, the trend of scratch research is very much because the capabilities and features of the scratch application can well support the Learning process. The following are bibliometric results for scratch research.

In recent years, scratch has become a popular tool for teaching programming and enhancing problem-solving skills, particularly among elementary and middle school students (Dúo-Terrón, 2023). Several studies have explored the relationship between Scratch programming and the development of computational thinking, logical reasoning, and creativity. For instance, studies have shown that scratch helps students break complex problems into smaller, more manageable tasks, thereby fostering problem-decomposition skills (Brennan & Resnick, 2012). Scratch has been identified as a useful tool for teaching problem-solving skills, especially for students in K-12 and higher education. Previous studies (Brennan & Resnick, 2012; Satria et al., 2024) highlight its potential to develop computational thinking and improve students' problem-solving abilities. However, there is limited systematic analysis of the research output in this area, particularly in identifying global research trends, collaboration networks, and key thematic areas.

However, while there is an increasing body of literature on scratch, significant gaps remain. For example, much of the existing research is centred on younger students, with limited studies addressing its effectiveness in higher education or adult learning contexts (Suseelan et al., 2022). Additionally, while scratch is often praised for enhancing problem-solving skills in specific domains, the broader impact across different cultural and educational contexts remains underexplored (Herro et al., 2022). Furthermore, previous research has not fully investigated the long-term impact of using scratch on students' problem-solving abilities, particularly regarding how these skills can be transferred to real-world applications (Marcelino et al., 2018). Existing studies have also shown limited engagement with interdisciplinary applications, such as integrating scratch with subjects like mathematics and science, which may provide a more holistic approach to learning (Oh & Kim, 2013; Tan et al., 2021). Given these gaps in the literature, this study aims to further explore the effectiveness of scratch as a tool for enhancing problem-solving skills, with a focus on its applicability across different educational contexts and age groups. Despite the increasing number of studies,

gaps in the literature persist regarding the long-term effects of Scratch-based learning on problem-solving, the comparative effectiveness of scratch versus traditional methods, and the integration of scratch with other emerging technologies such as artificial intelligence (AI) or the Internet of Things (IoT) (Ball & Bass, 2003). This bibliometric study addresses these gaps by providing a comprehensive analysis of the research landscape and offering directions for future research.

This bibliometric analysis is significant for several reasons: 1) The need for structured analysis: While various studies have explored the use of scratch in education, there has been no systematic analysis of the global research trends, collaboration patterns, and thematic development (Suseelan et al., 2022). This paper fills this gap by presenting a quantitative analysis of 359 research articles, providing an overview of the evolution of Scratch-related research. 2) Unique contribution: The study adds value by identifying emerging research areas in the context of scratch and problem-solving, such as the integration of scratch with project-based learning, the impact on cognitive skills, and the role of scratch in distance learning post-COVID (Pinto & Escudeiro, 2014). These insights are critical for guiding future educational research, especially as educators and researchers seek ways to integrate 21st-century skills into curricula (Kalelioglu & Gülbahar, 2014). 3) Practical implications for policy makers: The study's findings provide practical recommendations for policy makers on how to effectively incorporate Scratch-based learning into national educational frameworks, particularly in enhancing problem-solving skills among students (Marcelino et al., 2018)..

## 2. METHOD

This study adopts a bibliometric analysis methodology, utilizing data from the Scopus database. Bibliometric methods are used to quantitatively analyze scientific publications to identify research trends, collaboration patterns, and emerging topics in the field of Scratch programming and problem-solving. The method applied in this study is a bibliometric analysis using the Scopus database. The bibliometric analysis applies quantitative measures to analyze the scientific literature in specific fields of study, focusing on key actors, institutions, sources, articles, and important topics (Ellegaard & Wallin, 2015; Krabokoukis, 2023). In this study, the data were collected from the Scopus database.

Figure 1 presents a systematic process for filtering the Scopus database. This process is detailed in several progressive steps, each applying specific criteria to refine the document set for analysis. Initially, the search began with a broad query using the keywords "scratch" and "problem solving" or "problem-solving" (Dúo-Terrón, 2023; Suseelan et al., 2022), limited to publications published from 2000 to 2023. This initial step produced 471 documents. In the subsequent step, the document type is refined to include only conference papers and articles. This adjustment reduces the document count to 436. The next phase focuses on filtering documents by publication stage. By limiting the search to final publication stages, the document count slightly decreases to 433. Further refinement is applied by limiting the source type to conference proceedings and journals, resulting in 376 documents. This step ensures that the documents are sourced from reputable and relevant academic channels. The final step narrows the scope by filtering documents based on language, specifically English. This criterion reduces the document count to 359. Including this step is crucial to ensuring the documents are accessible and comprehensible for the intended analysis.

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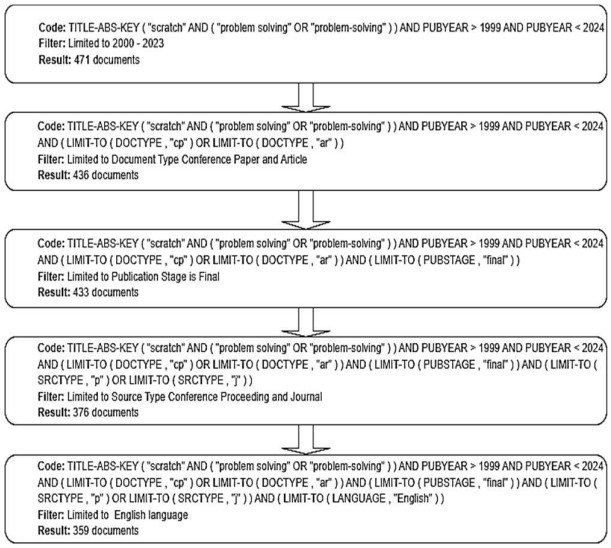


***Figure 1: Search Query in Scopus.***

The analysis was carried out using the Biblioshiny package in R and VOSviewer software. Biblioshiny was used to summarise the dataset, analyze annual publication trends, assess the impact of authors and affiliations, and identify key journals and articles. VOSviewer was used to visualize international collaboration and keyword co-occurrence, helping identify dominant themes within the research area. This comprehensive filtering process illustrates the meticulous approach taken to identify the most relevant and high-quality documents for bibliometric analysis. By applying these specific criteria, the process ensures a focused, pertinent dataset, enabling a more precise and insightful analysis of trends, key actors, institutions, sources, articles, and important topics within the field of study. Overall, the image effectively demonstrates the structured methodology of bibliometric analysis, highlighting the importance of systematic filtering to produce a refined, relevant dataset. Each step in the process progressively narrows the search, enhancing the quality and specificity of the documents included in the final analysis. This rigorous approach underlines the value of detailed bibliometric methods in scientific research.

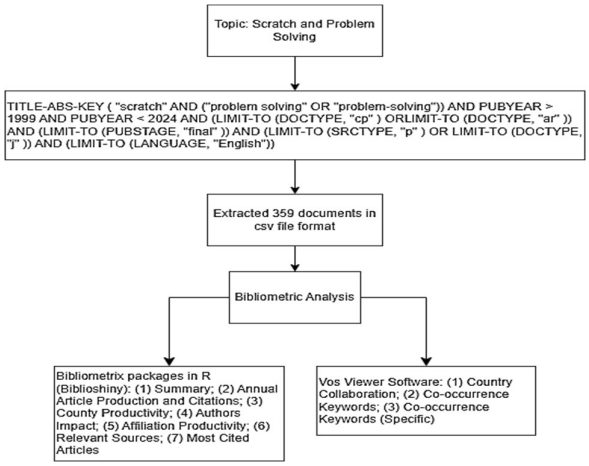
Topic: Scratch and Problem Solving
TITLE-ABS-KEY ( "scratch" AND ("problem solving" OR "problem-solving")) AND PUBYEAR > 1999 AND PUBYEAR < 2024 AND (LIMIT-TO (DOCTYPE, "cp" ) ORLIMIT-TO (DOCTYPE, "ar" )) AND (LIMIT-TO (PUBSTAGE, "final" )) AND (LIMIT-TO (SRCTYPE, "p" ) OR LIMIT-TO (DOCTYPE, "j" )) AND (LIMIT-TO (LANGUAGE, "English"))
Extracted 359 documents in csv file format
Bibliometric Analysis
Bibliometrix packages in R (Biblioshiny): (1) Summary; (2) Annual Article Production and Citations; (3) County Productivity; (4) Authors Impact; (5) Affiliation Productivity; (6) Relevant Sources; (7) Most Cited Articles
Vos Viewer Software: (1) Country Collaboration; (2) Co-occurrence Keywords; (3) Co-occurrence Keywords (Specific)

***Figure 2: Research Procedure.***

The flowchart provided the details of the process for a bibliometric analysis of research on the topic "Scratch and Problem Solving." The specific query returned 359 relevant documents, which were extracted in CSV format from the Scopus database, setting the stage for the bibliometric analysis. The analysis is divided into two distinct approaches using different tools: the Biblioshiny package in R and Vos Viewer software. Data were collected from the Scopus database using a comprehensive search query that included the keywords 'Scratch' and 'problem solving'. The search was restricted to documents published from 2000 to 2023. The dataset was refined by limiting the source type to conference proceedings and journals and filtering by language to ensure document accessibility and comprehensibility. This process resulted in a final set of 359 documents, ensuring high-quality data for the bibliometric analysis.

## 3. RESULTS AND DISCUSSION

The Biblioshiny package, an R-based tool for bibliometric analysis, is used to perform several critical analyses, such as (1) Summary of the dataset; (2) Annual article production and citation trends; (3) Country productivity, highlighting the geographical distribution of research contributions; (4) Author impact analysis, assessing the influence and contributions of individual researchers; (5) Affiliation productivity, focusing on the research output of institutions; (6) Analysis of relevant sources, identifying key journals and conferences; (7) Identification of the most cited articles in the dataset.

Parallelly, Vos Viewer software is employed to visualize and analyze the following aspects, such as (1) Country collaboration, mapping international research partnerships and networks; (2) Co-occurrence of keywords, providing insights into prevalent themes and topics within the field; (3) Specific co-occurrence of keywords, offering a more detailed examination of how particular terms and concepts are interrelated. Together, these tools enable a comprehensive bibliometric analysis, offering both quantitative and qualitative insights into the research landscape of "Scratch and Problem Solving." The combined use of the Biblioshiny packages in R and VOSviewer ensures a robust analysis, leveraging the strengths of each tool to provide a holistic view of the topic. All analyses were conducted using R version 4.4.1 and Vos Viewer version 1.6.20, running on a Lenovo (Intel Core i5 – 10th generation) with 8 GB RAM and a 512 GB SSD. Researchers encountered no difficulties running this software on the computer, and all processes ran relatively quickly.

***Table 1: Data Summary.***

| Content | Result |
|---|---|
| **General Information** | |
| Periode | 2000 - 2023 |

| Content | Result |
|---|---|
| Number of sources (journal) | 287 |
| Number of documents | 359 |
| Annual growth rate | 9.75 % |
| Number of citations per document (average) | 24.2 |
| **Document Content** | |
| Keywords plus | 2317 |
| Author's keywords | 982 |
| **Author** | |
| Authors | 986 |
| Authors of a single-author document | 45 |
| **Author's Collaboration** | |
| Documents of a single author | 45 |
| Co-authors per document | 3.09 |
| International co-authorships (%) | 17.83 |

Table 1 presents the trend in research on scratch and problem-solving from 2000 to 2023. The table above shows there are 283 journals with 359 articles—the research trend. The growth of research on this is very good at 9.75%; it increases every year, with a significant increase starting in 2004. The curve in Figure 1 looks like it's diving upwards. Until 2023, there are 359 articles, 986 authors, and 45 authors of single. This value, 3.09, indicates the average number of authors per academic document. This means that, on average, each document has about 3 authors. This percentage, 17.83%, represents the proportion of documents that involve international collaboration among authors. In this context, 17.83% of the documents have authors from different countries working together, and problem-solving research is a growing field.

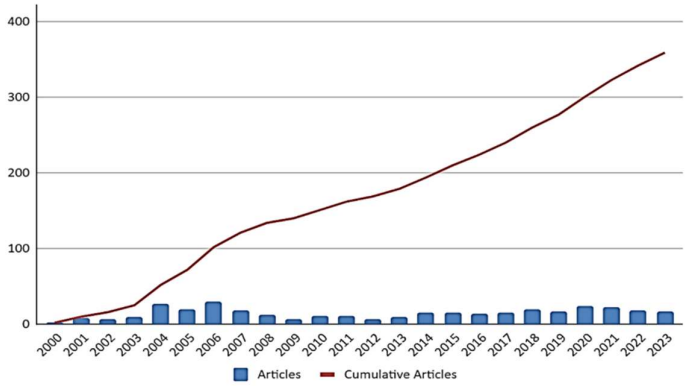


***Figure 3: Annual Number of Articles and Cumulative Articles.***

Based on Figure 3, the publication of research articles on scratch and problem-solving continues to grow, because the purpose of education is skills and the use of technology in learning. In 2004, development increased, but in 2009-2012 there was a decrease due to a shift in publication trends. In 2013-2023, development increased again, driven by the popularity of gadgets such as smartphones, tablets, and iPads launched in 2010, which became increasingly common. The job trend for programmers has changed the purpose of education. To fulfil 21st-century skills.

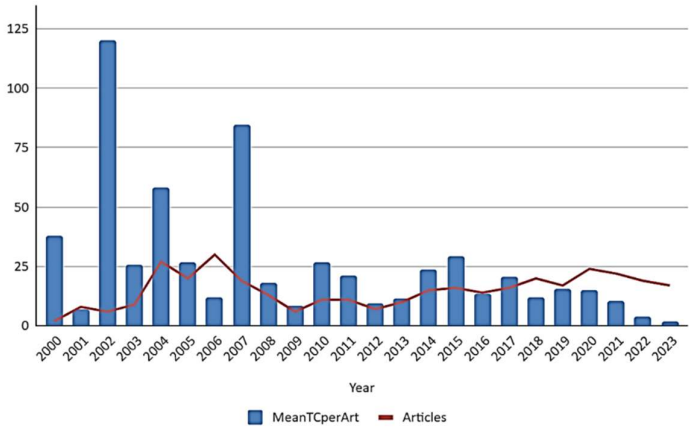


***Figure 4: Annual Number of Articles and Average Citation per Article Annually.***

Figure 4 shows the development of problem-solving and scratch research from 2000 to 2023. The bar chart shows the number of articles published each year, and the red line on the diagram shows the average citation per article. The citation pattern is not the same every year; the most citations are in 2000, 2002, 2004, and 2007. The most citations are in 2002, indicating that articles published that year influenced the research trend. In other years, the citations varied but seemed stable or increased, indicating that this field continues to develop with new research.

***Table 2: List of the Countries with the Most Articles.***

| No. | Country | Total Articles | Total Citations | Total Citations/ Total Articles |
|---|---|---|---|---|
| 1 | USA | 273 | 3281 | 12.02 |
| 2 | China | 134 | 611 | 4.56 |
| 3 | Japan | 45 | 258 | 5.73 |
| 4 | Germany | 54 | 244 | 4.52 |
| 5 | Switzerland | 7 | 228 | 32.57 |

Table 2 shows the top 5 countries contributing to problem-solving and scratch research, ranked by the number of articles. The USA has the most with 273 articles, followed by China with 134, Japan, Germany, and Switzerland with 45, 54, and 7 articles, respectively. The citation column shows the number of times the article was cited. The USA is in first place with 3,281 citations, with a citation per article of 12.02. The USA is still leading. Research in China totalled 611 citations, with a per-article citation count of 4.56. Japan and Germany: Japan's total articles are more than Germany's, but Japan's citations are higher at 258, while Germany's are 244, so Japan's average per-article citation is higher at 5.73, ranking Japan third and Germany fourth. Switzerland has the smallest total of 7 articles with 228 citations, giving an average citation per article of 32.57. This ranks it first, beating the USA, and shows that Switzerland's citations contribute more to research in this field.

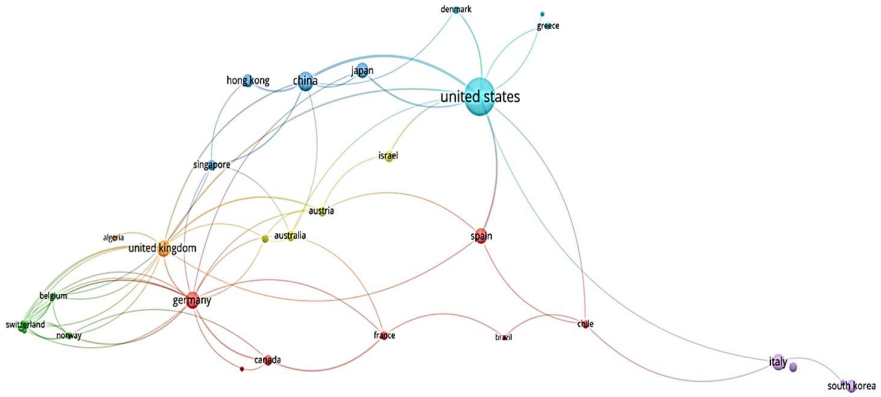


***Figure 5: Illustration of International Cooperation in Research.***

Figure 5 shows a network map of countries. The nodes in this graph represent countries, and the lines connecting them

indicate a relationship or interaction between them. Each node is labelled with a country name. Nodes vary in size, with some nodes larger than others. The largest node is the USA, followed by Germany. The nodes have different colours, indicating certain groupings or categories. Nodes are connected by coloured lines that indicate the type or strength of the relationship. The positions of the nodes indicate their interconnectedness, with nodes that are interconnected tending to be close together. The main nodes that stand out are the USA and Germany, which are larger and have more connections than other nodes. In Figure 3, Germany stands out with the most international research collaborations, followed by the UK. The Asian countries with the most collaborations are China, Japan, Singapore, and Hong Kong, while South Korea has the fewest. In European countries, collaboration is very strong, as seen in the number of trajectories in Switzerland, Belgium, Norway, the UK, and Germany.

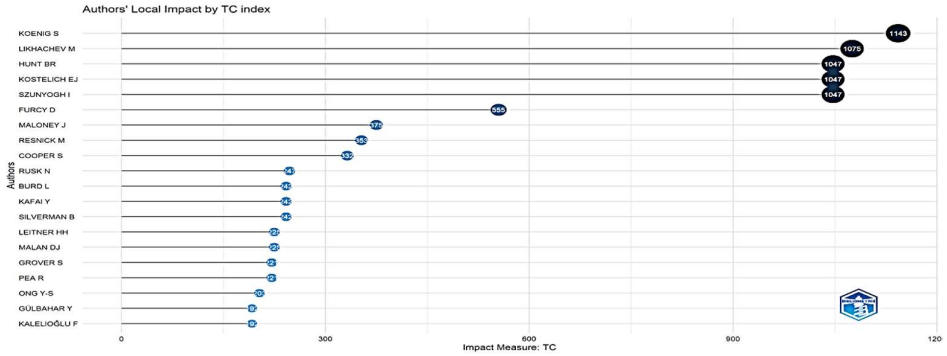


***Figure 6: Illustration of the Author's Impact (Total Citation) in Research.***

***Table 3: Articles Production based on Affiliation.***

| Affiliation | Country | Articles |
|---|---|---|
| The Chinese University of Hong Kong | China | 12 |
| Carnegie Mellon University | USA | 8 |
| Max-Planck-Institut Fur Informatik | Germany | 8 |
| Nanyang Technological University | Singapore | 8 |
| Univ. Autònoma de Barcelona | Spain | 8 |
| Aalborg University | Denmark | 7 |
| National Central University | Taiwan | 7 |
| Budapest University of Technology and Economics | Hungary | 6 |
| Drexel University | USA | 6 |
| Universiti Kebangsaan Malaysia | Malaysia | 6 |

Figure 6 shows the author's impact (total citations) in problem-solving and scratch research. The author with the highest impact is Koening S with 1143, and the lowest is Kalelioglou with 92. Table 3 shows the academic affiliations that contributed to problem-solving and scratch research. The table shows the number of articles produced by the institutions. The Chinese University of Hong Kong produced 12 articles; for institutions in the USA, Germany, Singapore, Spain, Denmark, Taiwan, Hungary, and Malaysia, the same articles produced were 8, 7, 6, 6, 7, and 6, respectively. In Southeast Asia, Malaysia is involved in the research.

***Table 4: Articles Production based on the Source.***

| Sources | Total Articles | Total Citations | H-Index |
|---|---|---|---|
| ACM International Conference Proceeding Series | 9 | 72 | 5 |
| Proceedings - Frontiers in Education Conference, FIE | 6 | 55 | 5 |
| Education and Information Technologies | 5 | 80 | 4 |
| Lecture Notes in Computer Science | 4 | 186 | 4 |
| ASEE Annual Conference and Exposition, Conference Proceedings | 8 | 25 | 3 |
| Theoretical Computer Science | 4 | 39 | 3 |
| Artificial Intelligence | 3 | 639 | 3 |
| ACM Transactions on Computing Education | 3 | 140 | 3 |
| IEEE Global Engineering Education Conference, Educon | 3 | 61 | 3 |
| Proceedings of The National Conference on Artificial Intelligence | 3 | 527 | 2 |

Table 4 shows the top 10 journals by total citations, sorted by the number of publications on problem-solving and scratch research. The most articles in the ACM international conference proceedings series, with 9 journals and an H-index

of 5, but the highest citation is 639 with 3 articles in the artificial intelligence journal; the second-ranked citation is in the proceedings of the national conference on artificial intelligence with 527 citations from 3 articles. The lowest citation count is in the journal ASEE Annual Conference and Exposition, Conference Proceedings, with 25 citations from 8 articles. The number of citations indicates that the research is influential in problem-solving and Scratch skills, is important to the journal's prestige, and demonstrates that the research published in the journal is recognized and used more widely in the academic world.

***Table 5: Ten Most-Cited Articles.***

| Title | Journal | Scimago Rank | Year | Normalized Total Citations | Total Citations |
|---|---|---|---|---|---|
| The effects of teaching programming via scratch on problem-solving skills: a discussion from learners' perspective | Informatics in Education | Q1 | 2014 | 8.18 | 192 |
| Designing for deeper learning in a blended computer science course for middle school students | Computer Science Education | Q1 | 2015 | 7.56 | 221 |
| Computational thinking in programming with scratch in primary schools: a systematic review | Computer Applications in Engineering Education | Q1 | 2021 | 6.38 | 67 |
| Computational thinking and media & information literacy: an integrated approach to teaching twenty-first century skills | TechTrends | Q1 | 2016 | 6.17 | 82 |
| Computational thinking and mathematics using scratch: an experiment with sixth-grade students | Interactive Learning Environments | Q1 | 2020 | 6.02 | 90 |
| Creativity development with problem-based digital making and block-based programming for science, technology, engineering, arts, and mathematics learning in middle school contexts | Journal of Educational Computing Research | Q1 | 2023 | 5.41 | 10 |
| Computational thinking development through creative programming in higher education | International Journal of Educational Technology in Higher Education | Q1 | 2017 | 5.31 | 104 |
| The effect of a programming tool scratch on the problem-solving skills of middle school students | Education and Information Technologies | Q1 | 2022 | 5.03 | 19 |
| The effects of using different tools in programming teaching of secondary school students on engagement, computational thinking, and reflective thinking skills for problem solving | Technology, Knowledge, and Learning | Q1 | 2020 | 4.88 | 70 |
| Alice, greenfoot, and scratch - a discussion | ACM Transactions on Computing Education | Q1 | 2010 | 4.68 | 111 |

Table 5 is the ten most cited articles, articles published in journals with a Q1 ranking ranging from 2014-2022, the first ranked article is The Effects of Teaching Programming via Scratch on Problem Solving Skills: A Discussion from Learners' Perspective published in the journal Informatics in Education in 2014, the citation rank in the journal is 8.18 which means that it has a large influence and is often cited, the total citations of this article are 192. The second-ranked article, titled "Designing for deeper learning in a blended computer science course for middle school students," in the journal Computer Applications in Engineering Education (Q1, 2015), has total citations higher than those of the first-ranked article (221). Still, its citation rank in the journal is lower at 7. 59. The article with the highest year in 2023 is Creativity Development With Problem-Based Digital Making and Block-Based Programming for Science, Technology, Engineering, Arts, and Mathematics Learning in Middle School Contexts published in the Journal of Educational Computing Research journal with a citation rating of 5.41 out of a total of 10 citations ranked sixth. The last rank of the article with the title "Alice, Greenfoot, and Scratch - A Discussion," published in the ACM Transactions on Computing Education in 2010, is 4.68, with a total of 111 citations. This article is quite widely cited, but its average influence compared to other journals is lower.

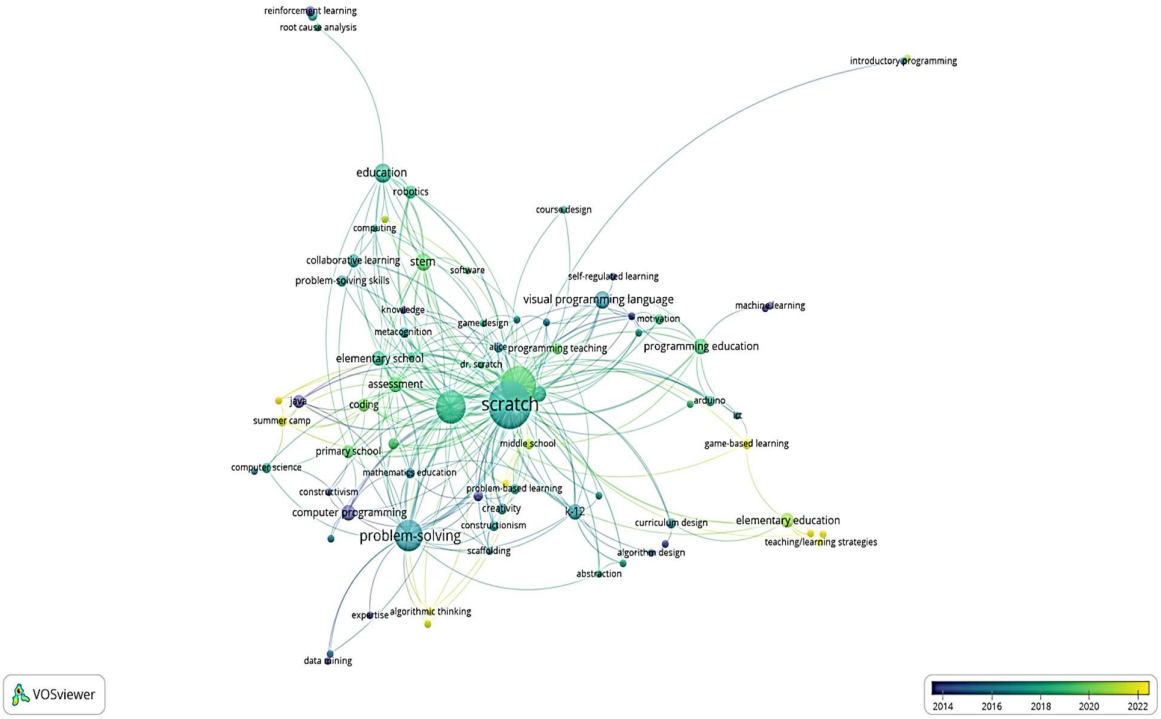


***Figure 7: Co-occurrence Keyword.***

Figure 7 is an overview of the occurrence of keywords in problem solving and scratch research, nodes represent keywords, lines show the relationship between keywords, the largest nodes in this map are scratch, problem solving, education, programming languages, assessment, STEM, elementary school, programmer education, and some skills in mathematics education, some terms in this map show the relevance of scratch and problem solving to other fields.

Problem-solving nodes are related to computer programming, education, maths, problem-based learning, creativity, constructivist thinking, and algebraic thinking. Scratch nodes are related to various topics, including elementary school, game design, high school, coding, assessment, metacognition, and some educational skills. Problem solving and scratch influence or correlate with other fields such as curriculum development, learning strategies, data development techniques, course design, introductory programming, root cause analysis, and learning reinforcement. The multidisciplinary skills are interrelated in Figure 9, which serves as a conceptual map that guides researchers in developing further research and in understanding the interconnectedness of research themes and concepts related to problem-solving and scratch.

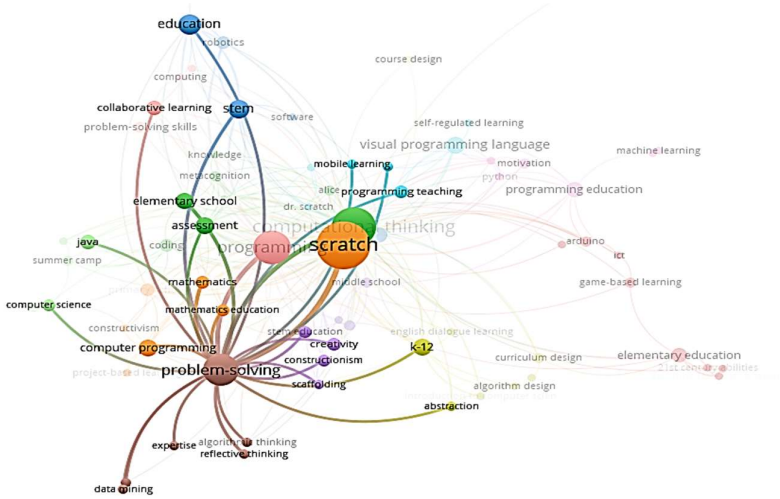


***Figure 8: Focus Keywords "Problem Solving".***

Figure 8 focus on the keyword problem-solving. From the map, the lines whose colours look clearer show a strong relationship between the nodes. The problem-solving node is related to the scratch node; the relationship between these nodes shows several concepts that can be developed, including computer programming, mathematics education, mathematics, creativity, constructivism, and scaffolding. Problem-solving skills in mathematics education can be assessed in basic education through several learning skills. Problem-solving and scratch in education can be presented through programming and mobile learning. These bibliometric results are consistent with empirical studies showing that digital programming environments such as scratch can significantly enhance students' mathematical problem-solving and computational thinking skills (Cevikbas & Kaiser, 2022; Papadakis, 2021). Similarly, research in Teaching Mathematics indicates that digital learning environments contribute to the development of flexible strategies and conceptual understanding in mathematical problem-solving (Branislav & Vesna, 2023).

Integrating scratch into educational methods has proven beneficial for improving students' problem-solving skills. However, it is difficult to teach pupils how to utilize programming to solve problems. One of these issues, according to Brennan and Resnick (2012), is a "tension between technology and learning," in that a perception of programming difficulty may impede mathematical learning. Scratch's user-friendly, interactive nature enables students to perceive and manipulate programming principles, rendering abstract concepts more concrete and understandable. Students engage in iterative problem-solving as they create Scratch projects, identifying challenges, brainstorming solutions, testing their ideas, and refining them (Ball & Bass, 2003; Satria et.al., 2024). This finding aligns with recent studies highlighting the role of digital environments in mathematics learning. Several works published in Teaching Mathematics* emphasize that integrating technology and digital platforms can significantly enhance mathematical problem-solving and reasoning. Petrović and Stojanović (2021) found that ICT tools such as Scratch and GeoGebra improve students' conceptual understanding and engagement in mathematics learning. Similarly, Kovačević and Marić (2022) showed that students develop more flexible strategies and reflective thinking when digital tools support problem solving. Moreover, Branislav and Vesna (2023) confirmed that digital learning environments foster interactive and adaptive problem-solving experiences, encouraging both individual and collaborative learning. These findings reinforce the current bibliometric analysis, showing that Scratch-based learning is part of a broader digital transformation in mathematics education, which aims to develop computational, critical, and creative thinking skills essential for 21st-century learners. Research trends combining scratch and problem-solving from 2000 to 2023 include the Pre-Scratch phase (2000–2007), which focused on visual programming and problem-solving in general. Research on the need for more accessible programming tools to teach problem-solving. Studies on the relationship between programming and the development of thinking skills. The introduction phase (2007-2010) saw the emergence of early studies exploring the potential of scratch for teaching problem-solving. descriptive research on the use of scratch in the classroom and its impact on students' problem-solving skills. Focus on the benefits of scratch in developing logical and algorithmic thinking. The expansion phase (2010-2015) saw a significant increase in publications linking scratch to problem-solving. The emergence of experimental studies comparing the efectiveness of scratch with traditional methods. Research on using Scratch to teach specific problem-solving concepts, such as problem decomposition and abstraction, in the Deepening phase (2015-2019) describes a more in-depth study of students' cognitive processes when using Scratch for problem solving. Longitudinal research tracks students' problem-solving skills over several years. Focus on integrating scratch with other pedagogical approaches, such as project-based or inquiry-based learning. Diversification Phase (2019-2023): Exploration of the use of scratch in broader problem-solving contexts, such as social or environmental problem-solving.

Research on the use of scratch in distance and hybrid learning, especially after the COVID-19 pandemic. Studies that combine scratch with new technologies such as AI or the Internet of Things to enhance problem-solving in teaching. The methodological trend is a shift from case studies and qualitative research to more rigorous experimental designs. The increasing use of mixed-methods approaches that combine quantitative and qualitative data, such as the adoption of learning analytics technology to analyze students' problem-solving processes in greater depth. At the same time, contextual trends include the increase in cross-cultural research comparing the effectiveness of scratch globally. Focus on teacher professional development in using Scratch to teach problem-solving. Studies on the integration of scratch into the standard curriculum and its impact on education policy (Fagerlund, 2021; Kalelioglu & Gülbahar, 2014; León et al., 2016). The interdisciplinary trend is the expansion of research into fields beyond computer science, such as math, science, and art, and the exploration of using Scratch to develop problem-solving skills that can be transferred across domains. And technology trends include research into integrating scratch with new technologies such as robotics, AR/VR, and artificial intelligence. Studies on the use of scratch in the context of STEAM (Science, Technology, Engineering, Arts, and Mathematics) education (Jeon & Lee, 2014; Oh & Kim, 2023; Tan et al., 2021).

As educational paradigms shift, adding tools like Scratch to the curriculum will be critical for improving students' problem-solving skills (Broza et al., 2023; Kritzer & Smith, 2020; Marcelino et al., 2018; Pinto & Escudeiro, 2014). Future research should examine the long-term effects of Scratch-based learning and how it might improve educational methods across a variety of scenarios. Educators who embrace new ways of teaching and learning can better equip students to navigate and thrive in an increasingly complex, technologically driven society. Mathematically and computationally rich pedagogical innovations help children

develop pattern-generalization and abstraction skills, leading to an interplay between the two. Recent developments in mathematics education research emphasize the growing influence of digital learning environments on students' problem-solving abilities. Studies published in Teaching Mathematics* highlight how integrating technology can improve students' engagement and conceptual understanding during mathematical problem-solving tasks (Petrović & Stojanović, 2021). Kovačević and Marić (2022) further demonstrate that digital tools foster students' strategic flexibility and reflective thinking when solving complex mathematical problems. In a similar vein, Branislav and Vesna (2023) found that digital learning platforms enable adaptive, interactive problem-solving, supporting both individual exploration and collaborative learning. These findings align with the present bibliometric analysis on scratch-based learning, reinforcing the notion that visual programming environments not only enhance computational thinking but also promote meaningful digital-based problem-solving experiences. Hence, the integration of scratch into mathematics education can be seen as part of a broader trend toward digitized learning ecosystems that cultivate critical, creative, and analytical reasoning skills essential to 21st-century learners.

## 4. CONCLUSION

This effort aims to review the existing literature and provide key ideas on problem-solving and learning from scratch. The use of scratch as a tool for learning and problem-solving has shown great promise for improving educational outcomes. Scratch allows pupils to acquire critical thinking and computational skills in ways that traditional teaching techniques may not adequately address. Scratch's visual nature simplifies complex concepts, making them accessible to learners of all skill levels and encouraging deeper understanding of the subject matter. Scratch learning, as a method for fostering students' problem-solving abilities, has seen considerable growth from 2000 to 2023, with the number of studies increasing annually. Within this timeframe, 359 publications were sourced from 287 academic journals that delved into this subject. The United Statesemerged as the focal point of research on the correlation between scratch programming and problem-solving, followed closely by China. The primary reason for the United States' dominance in publications exploring the relationship between scratch programming and problem-solving is the origin of scratch as a software application developed in a laboratory setting on a U.S. campus. The ACM International Conference stands out as the primary venue for disseminating research on the nexus between scratch programming and problem-solving, though other platforms also play a significant role. Various scholars have made noteworthy contributions to advancing knowledge in this domain, with the Chinese University of Hong Kong in China standing out as particularly influential. Our findings show that scratch has a favorable impact on students' problem-solving skills, as indicated by higher engagement, improved logical reasoning, and a stronger desire to experiment and iterate on solutions. Teachers observed a more dynamic classroom atmosphere that promotes collaboration and creativity. The insights from these findings offer valuable guidance to researchers seeking to understand the interplay between scratch programming and problem-solving, thereby advancing this field in the future. Future research will address the need for two computing devices per student to assess students' computational abilities using Scratch. This bibliometric analysis of Scratch and problem-solving research provides valuable insights into the growth and impact of this area of study. The findings underscore scratch's role in enhancing students' problem-solving abilities and highlight important research gaps that need to be addressed. Future research should explore the long-term effects of Scratch-based learning, its integration with other educational tools, and its potential to foster global collaboration in educational settings. For educators and policymakers, this study offers practical recommendations for incorporating Scratch into national education systems to improve students' problem-solving skills in the digital age. Based on the analysis and interpretation of the bibliometric results, the research findings can be explained in several contexts, namely theory, practice, and education policy.

**Key research trends**: the study reveals the growing importance of scratch in problem-solving education, with significant growth in research publications starting around 2004. The annual growth rate in publications is 9.75%, reflecting increased interest in computational thinking and digital literacy in education. First, emerging topics: key themes from recent years include computational thinking, STEM education, and project-based learning. These topics align with global educational movements emphasizing hands-on learning and critical thinking (Brennan & Resnick, 2012). Second, research gaps: despite the growing body of research, longitudinal studies that measure the long-term impact of scratch on students' problem-solving abilities remain. There is also a lack of research on the cross-cultural applications of scratch and on its effectiveness across different educational contexts (Pinto & Escudeiro, 2014).

**Collaboration networks**: the study finds a strong international collaboration network, with the U.S. and China leading in publications and citations. Notably, Switzerland shows high citation impact, suggesting that smaller countries can have significant contributions. The U.S.'s dominance reflects scratch's origin, but international collaboration, especially between Europe and Asia, plays a key role in expanding the research scope. (Satria et al., 2024) The high level of international collaboration shows that scratch as an educational tool for developing problem-solving skills is recognized globally. It also underscores the importance of international collaboration in expanding the understanding and application of scratch across countries with diverse educational needs.

**Impact on theory and practice**: for educators, the findings underline scratch's potential as a tool for teaching problem-

solving skills. It encourages active learning and collaborative problem-solving, key aspects of modern education. For policymakers, the study's insights suggest the need to integrate scratch more effectively into curricula to foster 21st-century skills such as creativity, critical thinking, and computational literacy.

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